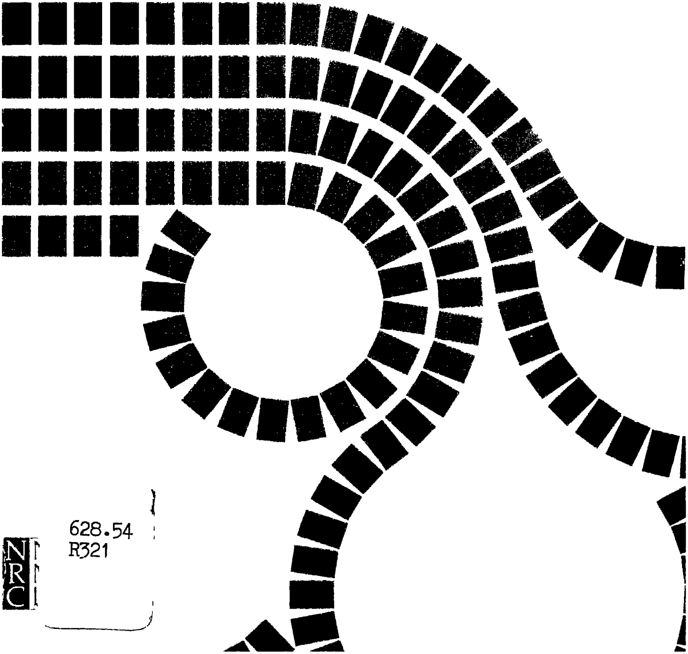
Reducing Hazardous Waste Generation



NRC

Reducing Hazardous Waste Generation

An Evaluation and a Call for Action

Committee on Institutional Considerations in Reducing the Generation of Hazardous Industrial Wastes

Environmental Studies Board

Commission on Physical Sciences, Mathematics, and Resources
National Research Council

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Preface

The Committee on Institutional Considerations in Reducing the Generation of Hazardous Industrial Wastes was organized in September 1983 to explore the nontechnical factors that influence decisions by industrial management to reduce the generation of hazardous waste The committee, sponsored by the Andrew W Mellon Foundation and National Academy of Sciences Endowment funds, was asked to examine the public policy approaches that may lead industries to reduce generation of hazardous waste The report therefore focuses on reduction in generation of hazardous waste and not treatment, although the committee recognizes that treatment alone or in conjunction with reduction in generation can also be an effective approach to a specific problem

Industrial decisions about waste reduction are made for varied and complex reasons The committee's task to understand these reasons was constrained by the lack of comprehensive and systematic data on the amount of waste reduction that has occurred over the broad range of industry and by the lack of extensive literature on the nontechnical aspects of waste reduction Therefore many of the observations in the report are based on the presentations made to the committee, reports on topics related to waste reduction, and workshop discussions In formulating its conclusions, the committee relied on these observations and on the collective experience of its members with large and small firms, public administration at the federal and state levels, and consultancy with industry (see Appendix E) After considerable discussion, there was little disagreement among members about the basic conclusions of the report

Among the "institutional," or nontechnical, factors the committee considered were economic factors, such as capital costs of waste reduction equipment; regulatory factors, such as stringency of standards, and psychological factors, such as attitudes toward change Many such factors were considered in the course of the study, and some of them were not discussed separately in the text for a variety of reasons. For example, public involvement and understanding of industrial efforts to reduce the generation of hazardous waste is a factor affecting decisions Public involvement is related to many factors that are

presented, such as the public's role in ensuring a predictable regulatory program, thus it is discussed in several different contexts throughout the report.

Time constraints did not permit the committee to look in detail into several issues that members recognized as being important to the public discussion on waste reduction. As mentioned in several places throughout the report, small businesses face a unique set of nontechnical considerations in their decisions about waste generation and reduction. The complex issue of the generator's liability for remedial action and how it affects decisions about waste generation is also important. In addition, a uniform definition of hazardous waste is essential to devising an accepted way for collecting data on waste generation. The committee hopes that this report will stimulate future work on these and other issues that it has raised.

In considering the relative importance of the various factors, the committee concluded that no single factor or group of factors is the most important in all circumstances. The relative importance of the factors depends on the dynamic interplay of such variables as the type and size of the industry or plant and the amount of waste reduction that has already been achieved. In this report, the dynamic character of waste reduction programs is used as a framework within which to explore the relative importance of the nontechnical factors and the potential effectiveness of public policy alternatives at different stages in the nation's waste reduction effort.

The committee conducted its study through a series of meetings and consultations with experts in the field. It reviewed many documents about hazardous waste management and other related fields (see Appendix C), but, as mentioned above, its work was constrained by the lack of peer-reviewed literature in the area of waste reduction. Indeed, this is one of the first attempts at a comprehensive work on institutional considerations. Many examples of achievements in waste reduction were brought to the committee's attention. It is difficult to generalize, however, from a series of examples where there are limited data to suggest their wider applicability. Much of the report therefore represents the personal experience and judgment of the committee after consideration of the facts brought before it.

To test this judgment, the committee organized a workshop in May 1984 at which a group of experienced people from industry, state and federal government, and environmental groups (see Appendix D) were asked to discuss the issues raised in this report. Discussion papers prepared by the committee were circulated in advance and served as the focus of the interaction. The papers discussed the institutional barriers to more effective waste reduction in the United States. The workshop participants responded that to focus on the barriers to waste reduction seemed unnecessarily negative, in that such a focus did not highlight the achievements that have been made with waste reduction and wrongly implied that opportunities for waste reduction are limited. The

committee then framed the ideas in this report in a more neutral tone, focusing on "factors affecting industrial decisions about waste generation." The committee is grateful to the participants for their candid contributions to the discussion and their helpful insights.

It is with great sadness that the committee reports that one of the members, Anthony O. Facciolo, Jr., passed away in June of 1984. He not only brought a unique perspective to the committee both as a lawyer and as a manager of a small metal finishing firm, but also brought pertinent insights and a personal warmth.

The Hazardous and Solid Waste Amendments of 1984, the reauthorization of the Resource Conservation and Recovery Act by the 98th session of Congress, states that the national policy of the United States is, wherever feasible, to reduce or eliminate the generation of hazardous waste as expeditously as possible. Although this report was prepared before the final reauthorization of RCRA, it analyzes actions that would accomplish the reduction in generation called for in the Act.

The committee thanks the many people who provided data and their insights. Adam M. Finkel assisted in the preparation of the text. Lori Segall catalogued a considerable number of reports and other background material that were most helpful. The committee also wishes to express appreciation to the NRC staff: Ruth DeFries, staff officer for this study, Paul Schumann, NRC Fellow, Myron Uman, executive director of the Environmental Studies Board, and Joyce Fowler, administrative secretary, for their patience, long hours, dedication, and competence. Finally, I want to thank my colleagues on the committee who provided excellent professional experience and insight and who worked with exceptional dedication and energy to bring this task to completion and this report to fruition.

RAYMOND C. LOEHR
Chairman

Contents

Summary of Analysis and Conclusions

This report examines key institutional, or nontechnical, factors that affect the generation of hazardous waste by industry. It provides a framework for evaluating public policies, both regulatory and nonregulatory, to reduce the generation of hazardous waste. In undertaking its task, the committee recognized that the report itself was not expected to provide detailed solutions; rather it was expected to provide a foundation upon which improved public policies for hazardous waste management could be built.

The report's underlying premise is that waste reduction should be an integral component of any national waste management strategy. For the purposes of this report, "waste reduction" refers not only to in-plant process modifications that reduce the volume or degree of hazard of hazardous waste generated, but also to reuse and recycling practices.

This report is one of the first to deal with nontechnical factors affecting the generation of industrial hazardous waste. Because little study has been devoted to this topic, committee members have relied on the presentations made to the committee, reports cited in Appendix C, workshop discussions, and ultimately their own experience and judgment in formulating their recommendations. The committee hopes that this report will stimulate public discussion of this subject.

FINDINGS

1. Development of industrial waste reduction programs is a dynamic process that can be expected to grow in sophistication over time in three identifiable phases.

The considerations affecting decisions by individual firms to reduce hazardous waste depend on the phase of development of the individual waste management programs. The committee has distinguished three phases in the development of industrial waste reduction programs. In reality, the phases overlap; they nonetheless provide a helpful guide for discussing the relative importance of different considerations at different times and for different firms.

In the initial phase, firms consider for the first time changing their current waste management practices in order to exploit low-cost waste reduction opportunities. These first steps typically involve relatively unsophisticated technical approaches such as "good housekeeping" practices and separation of waste streams. Although they are technically simple, these first steps often achieve substantial waste reductions.

The second phase of waste reduction programs is the development phase. In this phase, firms review and implement more comprehensive strategies. The principal characteristic of waste reduction activity in the development phase is the increasing sophistication of the technology of waste reduction and the associated challenge to the engineering, operating, and financing skills of the firm's management. The capital expenditures in this phase are often greater than in the initial phase.

In the third phase of waste reduction efforts, designated in this report as the mature phase, firms begin to confront the political, economic, and technical limits of waste reduction activities. This phase is marked by requirements not only for technical sophistication in waste reduction, but also for a sophisticated risk assessment and management program for both industry and the nation.

2. <u>Nontechnical considerations critical to waste reduction decisions vary in importance as waste management programs become more sophisticated.</u>

In the initial phase, when firms first confront the need to change waste management practices, public policies, to be effective, should emphasize the dissemination and use of available technologies through the following:

- Educational programs for waste generators and engineers

- Dissemination of information through state-established authorities, university-based groups, trade associations, and other appropriate groups
- Fostering of competition for novel means to reduce generation
- Public demonstration of existing methods in a wide variety of actual situations
- Assistance to waste exchanges to enable them to play a more active role in arranging for recycling and reuse of materials

Programs to improve information dissemination and use are worthwhile in all phases of the waste reduction effort, but they are especially useful in the initial phase because of the relative lack of knowledge about waste reduction practices among many firms. Also, they are especially appropriate for small businesses, which may lack specially trained personnel.

Public policies in the initial phase should also be sensitive to the incentives for waste reduction created by "command and control" regulatory means. This sensitivity requires the following:

- Evaluation of existing legal exemptions to determine whether such exemptions inadvertently reduce incentives for waste reduction
- Changes in procedural requirements to allow greater flexibility for recycling and reuse
- Strengthening some standards to encourage waste reduction practices: (1) restrictions on materials allowed in landfills, (2) rapid phase-out of old, inadequate fills, and (3) strengthened long-term care requirements for land disposal options
- Effective program implementation to assure that the incentives for waste reduction reflected in regulatory standards are also reflected in actual practice
- Increasing the cost to waste generators for land disposal to a level consistent with the total social cost of land disposal options

Programs of regulatory reform and improvement are especially important in the initial phase because regulation can impart a critical strategic direction to the nation's waste reduction effort.

In the development phase of the nation's waste reduction effort, other factors can have priority. Because many of the least costly approaches have been

implemented in the initial phase, public policy must address the financial challenges associated with the implementation of increasingly sophisticated technologies. Loan or subsidy programs that were less important to the first phase may become more important. Regulatory approaches to provide the flexibility firms need to exploit increasingly sophisticated and innovative waste reduction methods are also needed.

Specific public policies important to this development phase include the following:

- Increased public education to ease siting difficulties for recycling facilities
- Support for research and development needed to adapt existing waste reduction technologies to individual applications
- Increased procurement of recycled goods for use by government and other organizations
- Low- or no-interest loans, guaranteed loans, or direct subsidies for waste reduction
- Tax deductions or credits for waste reduction expenditures
- Support for joint reduction strategies and facilities for small waste generators
- Modification of product quality standards on a case-by-case basis to encourage waste reduction
- Greater use of EPA authority to "list and delist" materials to encourage recycling and reuse
- Incorporation of the degree-of-hazard concept in the regulatory framework

In the mature phase of the waste reduction effort, research and development and risk assessment and management programs are especially useful. Firms are approaching the limits of technical sophistication in waste reduction. Accordingly, basic research to develop improved waste reduction methods is needed. Moreover, because waste reduction is so sophisticated and costly in this phase, there is a need for risk assessment and management programs, which attempt to balance the inevitably costly trade-offs that must be made between competing social interests.

During the mature phase of the waste reduction effort, public policies should therefore do the following:

* Define acceptable limits of waste reduction through a program of risk assessment and management
* Support research on new waste reduction technologies

CONCLUSIONS

1. The major portion of the industrial effort in the nation is now in the initial phase of hazardous waste reduction.

The committee observed that some firms and individual plants are already well along in implementing sophisticated waste reduction programs. In the committee's judgment, however, most of the industrial efforts in the nation are currently in the initial phase in the development and implementation of hazardous waste reduction programs. Significant opportunities exist to reduce the generation of hazardous waste; priority should be given to those public policies most suited to encourage such efforts in the initial phase.

2. Two general policy principles apply to all phases of the hazardous waste reduction effort:

* It is essential to properly price treatment and disposal during all phases of the waste reduction effort.

Industrial management will not have an incentive to undertake waste reduction if waste treatment and disposal options are priced below the true costs to society.

In particular, the committee believes that it is essential to increase the cost of land disposal options, such as landfills and surface impoundments, to bring their costs more in line with the true social costs of such options to the degree that these costs are currently understood.

* It is generally desirable to reduce the generation of hazardous waste. However, waste reduction should not be viewed as an end in itself. Regulatory standards ought to be based on health and environmental considerations.

Waste reduction policies should always be motivated by the concern for environmental protection. This principle applies in all phases of the waste reduction effort, although it is especially important in the mature phase, when the limits of technical, political, and economic feasibility are approached.

3. <u>While policies appropriate to the initial phase of the waste reduction effort are now needed, some actions must also be taken now in anticipation of the nation's transition to the second and third phases.</u>

In particular,

- A clear definition of hazardous waste and improved methods for obtaining data and tracking success in waste reduction are needed.
- Efforts are needed today to assure the regulatory flexibility necessary to accommodate the anticipated growth in the technological sophistication of the nation's waste reduction effort.
- Basic research on new waste reduction techniques is central to success in the third phase. Research is an activity requiring a long lead time, and basic research should begin while the nation is still in the initial phase.
- Effective risk management is essential to success in the mature phase, when the trade-offs between protection of public health and the environment and costs must be understood. Risk management requires a long lead time and should begin while the nation is still in the initial phase.

4. <u>Regulation must play a continuing role in the nation's overall waste treatment and disposal policy, but nonregulatory means are currently most likely to lead to waste reduction.</u>

In encouraging the identification and implementation of cost-effective and innovative ways to reduce the amount of hazardous waste that will be generated, nonregulatory approaches do not suffer from the same constraints inherent in regulatory mechanisms that directly control industrial processes. Nonregulatory approaches extend the range of waste reduction alternatives available to industrial management. As examples, information dissemination programs make more waste generators aware of waste reduction possibilities; financial incentives make more of these options feasible; and support for basic research on new waste reduction techniques increases the options available in the mature phase. These nonregulatory approaches to encourage waste reduction should play a major role in the nation's waste management strategy and should be discussed, evaluated, and implemented as soon as possible.

1
Introduction

SCOPE OF THE STUDY

Protection of human health and the environment through the proper management of hazardous industrial waste is an important societal goal. An essential component of strategies for waste management is reduction in the quantities of hazardous waste generated that require attention through treatment and/or disposal (National Research Council 1983, Office of Technology Assessment 1983).

The committee considers approaches that reduce the quantities or degree of hazard of hazardous waste generated to be beneficial to society. The relationships between reductions in the quantities of waste generated and risks to public health and environmental quality are not clearly understood. The relationships are not necessarily linear; for example, a decrease in the quantities of waste generated does not necessarily imply a directly proportional decrease in the risks to public health and environmental quality. In its deliberations, the committee did not distinguish between reducing the quantities and reducing the degree of hazard of hazardous waste because the current understanding does not permit it.

Reducing the quantities or degree of hazard of hazardous waste that is generated entails the application of technology, such as modifications in the production process or substitution of a product using different raw materials. Not all considerations in reducing the generation of hazardous waste are technical, however. There is a wide range of nontechnical factors affecting the generation of industrial hazardous waste, including

economics, regulation, availability of resources such as technology and information, and attitudes toward change.

In this chapter, several issues are raised regarding the definition of hazardous waste; estimates of how much hazardous waste is generated are discussed; the role of waste reduction in a comprehensive waste management scheme is described; and the committee's definition of the term "waste reduction" is given. A schematic description of the phases in the development of industrial waste reduction programs is also introduced.

In each of the phases of the conceptualized pattern of implementation of waste reduction strategies, various nontechnical factors affect industrial decisions about waste generation. These factors are explored in Chapter 2. In Chapter 3, the public policy approaches to encourage waste reduction are discussed in light of the dynamics of these nontechnical factors.

DEFINITIONS OF HAZARDOUS WASTE

Virtually all industrial activity generates some materials that are considered waste and are discarded because they are perceived to have no further economic use. The term waste can be defined as a "nonproduct material or energy output, the value of which is less than the costs of collecting, processing, and transporting for use" (Bower et al. 1977). According to this definition, materials that have economic potential for reuse, recovery, or recycling are not truly waste.

Certain wastes are defined as hazardous under the Resource Conservation and Recovery Act of 1976 (RCRA; PL 94-580) because they may

(a) cause or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or
(b) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed (42 USC 6903).

Regulations implementing RCRA regard wastes as hazardous if they are either "characteristic" wastes, i.e., ignitable, corrosive, reactive, or toxic (40 CFR 261.20-261.24), or specifically listed as hazardous (40 CFR 261.30-261.33).

Applying the formal definitions of hazardous waste to specific uses is not a straightforward task. There are many differences among state and federal governments, industry, and other parties as to which wastes should be included under the definitions.

Some states have elected to broaden the RCRA and EPA definitions of hazardous waste to include additional chemical compounds, waste produced by small-volume generators, and wastes specifically excluded by RCRA from regulation in the federal program (Office of Technology Assessment 1983). Additional complications in collecting data on hazardous waste generation arise because the definition in the federal regulations considers a recycled hazardous material a hazardous waste if it is a listed waste. A manufacturer, in contrast, may not consider a recycled material a hazardous waste if it is reused in a subsequent process on-site, since the material is never actually discarded. Also, a substantial fraction of the legally defined hazardous wastes are wastewaters that qualify as hazardous waste because materials specifically defined or listed as hazardous waste have been mixed with plant wastewaters; had the two waste streams not been mixed, the quantity of hazardous waste would be much less. Such differences as these pose substantial problems for analyzing and comparing data on the generation of hazardous waste.

For the purposes of this report, the committee did not consider it necessary to define hazardous waste precisely; instead, the RCRA statutory definition is the broad working definition for the study. The difficulties and differences in definition, however, themselves constitute one of the factors affecting industry's decisions about the generation of hazardous waste (see section on regulatory issues in Chapter 2).

ESTIMATES OF HAZARDOUS WASTE GENERATION

Estimates of the quantities of hazardous waste generated by industry vary widely, depending on the definition of hazardous waste used. The EPA, state agencies, and private organizations such as the Chemical Manufacturers Association (CMA) collect data on hazardous waste generation. EPA reported that about 264 million metric tonnes (71 billion gallons) of hazardous waste were managed in treatment, storage, and disposal processes and were regulated under RCRA in 1981 (Westat 1984).

Large portions of this quantity are mixtures of hazardous and nonhazardous wastes, which are defined under RCRA as hazardous. Using both state and federal definitions, the Office of Technology Assessment (1983) reported that industry generates some 255 to 275 million metric tonnes of hazardous waste annually.

Almost all of the federally regulated hazardous wastes (96 percent) generated in 1981 were managed at the site of generation. Recycling appears to be of increasing interest to waste generators. Of the 14,098 generators, 5700 indicated that recycling was used for some of their waste prior to 1981, and 7800 indicated that they expected to use recycling techniques after 1981.

The Chemical Manufacturers Association (1983) reported that the quantity of hazardous wastewater generated by the chemical industry (about 651 and 637 million metric tonnes in 1981 and 1982, respectively) exceeds the quantity of hazardous solid waste generated (about 6.4 and 4.5 million metric tonnes in 1981 and 1982, respectively) by 2 orders of magnitude. Over 97 percent of this wastewater is treated in wastewater treatment plants, however, with over 80 percent being treated on-site (Chemical Manufacturers Association 1983).

The differences in definition and the subsequent inconsistent treatment of data on hazardous waste generation make it difficult to obtain reliable historical data on generation and to estimate the amount of waste reduction that has occurred. While there are an encouraging number of documented situations where waste reduction has been implemented, data on the amount of waste reduction that has occurred on a national scale are lacking. Achievements in some specific cases are substantial; examples of successful waste reduction programs are documented in Campbell and Glenn (1982), Ministere de l'Environment (1981), Royston (1979), and in conference proceedings edited by Huisingh and Bailey (1982). It is difficult, however, to tell from the examples how much of the waste reduced is actually hazardous and not nonhazardous sludge, wastewater, or conventional air and water pollutants.

The lack of data on hazardous waste generation is recognized by many investigators (U.S. General Accounting Office 1984a; Petulla 1984). Because of the lack of data on the amount generated and the amount of waste reduction that has occurred at a national level, the committee could not address the question of how much hazardous waste is amenable to the use of waste reduction methods.

Making this estimate is further complicated because the obtainable level of waste reduction is strongly influenced by economic and political considerations as well as other factors. Although the committee cannot reliably estimate the amount of waste reduction that is possible, the committee's collective experiences reveal that opportunities do exist for reducing the generation of hazardous waste.

THE ROLE OF WASTE REDUCTION IN WASTE MANAGEMENT STRATEGIES

Figure 1.1 shows the relationships between the options a waste generator could consider in developing a strategy for managing hazardous waste. This simplified diagram has three levels of options: waste reduction; conversion

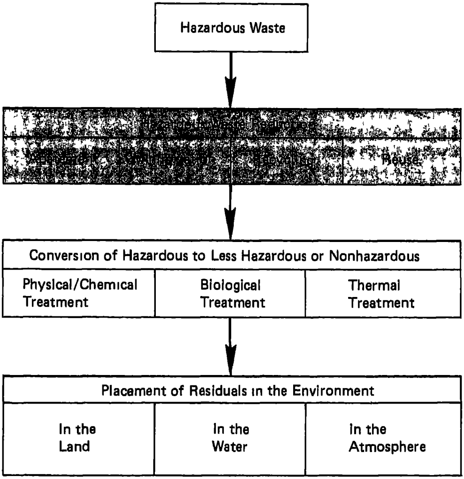

FIGURE 1.1 Waste management options. The screened tier is the area focused on in this study.

of hazardous waste to less hazardous waste; and placement of residuals in the environment. The focus of this study is on the upper tier. It must be recognized, however, that the other options have an indispensable role in the environmentally sound management of hazardous waste (see Appendix A).

To some, the term "waste reduction" is limited to in-plant changes in industrial production processes that reduce the generation of hazardous waste. The committee, however, includes both changes in production processes and recycling and reuse of hazardous materials, either at or away from the site of generation, in the definition of waste reduction. To simplify the terminology, in this report waste reduction is divided into four general categories: abatement, minimization, reuse, and recycling. The first two terms generally apply to in-plant process modifications. The other two refer to techniques that can be used either on or off the site of generation. Table 1.1 provides definitions and examples of the four terms.

Waste abatement refers to changes in industrial processes that eliminate or drastically reduce the quantities of waste produced. Technologies employing abatement are also called low-waste and nonwaste technologies. Substitutions of chemicals or changes in production processes can achieve waste abatement. Chemical substitutions may include the use of new reactants, solvents, or ingredients in processing. Process changes include those that increase internal recycling and those that produce a product through the use of alternative chemical routes. In the extreme case, the product might be replaced by a substitute, the production of which would generate smaller quantities of hazardous waste or waste that might be more easily treated to a nonhazardous form. Significant capital expense or extensive research and development activities are often needed with this approach.

As in the case of abatement, waste minimization reduces the quantity of waste through modifications within the production process, but in this case through good housekeeping practices that entail relatively low capital costs. Waste minimization can be used to reduce the amount of waste that must leave the site, and it can lower handling, shipping, and even treatment and disposal costs.

The categories of recycling and reuse are often used interchangeably, though differentiation between them can

TABLE 1 1 Categories of Hazardous Waste Reduction Methodologies

	Examples
1 Waste abatement Substitution of a new primary industrial process for an old process to eliminate or drastically reduce the quantity of waste produced	• Replacement of cyanide in electroplating solutions • Replacement of solvent-based paints by water-based ones
2. Waste minimization The reduction of the quantity of waste through good housekeeping practices or by the application of concentration technology. Often included is the reduction in hazardousness of waste through simple in-plant treatment.	• Separation of waste streams to permit recovery • Recovery of metals from electrodialysis • Neutralization of waste and precipitation of smaller volume sludges
3. Waste reuse The direct reuse of a waste stream, as is, or with very minor modification either by the plant that produces the waste or by others.	• Use of solvents from electronics industry in manufacture of paints • Use of refinery caustic in pulping of wood • Use of paint sludges as sealants
4. Waste recycling The reclamation of value from waste streams through the application of unit processes such as distillation, etc	• Waste oil refining • Solvent distillation • Secondary aluminum smelting • Iron salts from pickle liquor

be useful. Waste reuse generally occurs with little modification to the waste, whereas recycling generally occurs only after the valuable components of the waste have been separated from the other components of the waste stream. A residue of some sort is therefore produced when materials are recycled.

It is important to note that the reuse and recycling of hazardous waste must be undertaken with caution to avoid risks to public health and the environment. For example, improper storage of waste at recycling facilities and reuse of contaminated oil for dust control on roads could lead to severe problems. Some sites that currently require extensive cleanup action are, in fact, former sites of recycling and reuse facilities (e.g., U.S. General Accounting Office 1984b).

It is sometimes hard to decide whether a particular process in a particular case is a waste reduction or a treatment methodology. For example, incineration can be viewed as a technique for treating or detoxifying waste.

On the other hand, certain by-products in industry have a high solvent content and can be burned for their energy content. In this case, the burning may be considered as waste reduction via recycling or reuse. In general, waste reduction methodologies attempt to go further back in the production process to the source of the waste than does conventional end-of-pipe treatment of pollutants. Reduction methodologies employ engineering and chemical principles to reduce their generation or recover useful materials from them.

DYNAMICS OF WASTE REDUCTION STRATEGIES

The considerations affecting decisions by individual firms to reduce the generation of hazardous waste depend not only on technological and economic factors, but also on the stage of development of their waste management program. Ideally, public policies to encourage waste reduction would be flexible enough to allow shifts in emphasis as conditions change. The approaches that are appropriate to reduce the risks to the public and the environment at one phase of development differ from those that are appropriate at another time. For example, dissemination of technical information is important when generators begin to explore the possibilities for waste reduction. When generators require more capital-intensive techniques to achieve additional reductions, public policies for financial support become more important.

Some firms in the United States have sophisticated waste reduction programs and have successfully reduced the volumes of waste they generate. In many instances, significant cost savings have been realized in the process. Other firms are in the early phases of devising and implementing such programs. The experiences of the committee members suggest that the major portion of the waste reduction effort in U.S. industry is still in the early stages, and considerable opportunities exist for reducing the generation of hazardous waste.

Reductions in the generation of hazardous industrial waste can be expected to occur through a series of loosely defined and overlapping phases (Figure 1.2). At any time, some firms will be affected by considerations that operate most strongly in one phase, and other firms by those that operate in other phases. In the aggregate, national policy would have to address the full panoply of considerations, though some policies may deserve greater

INITIAL PHASE	DEVELOPMENT PHASE	MATURE PHASE
Firms consider changing waste management practices and implement low cost waste reduction opportunities	Firms develop and implement comprehensive strategies for waste reduction, often involving more capital intensive technologies	Reduction in generation approaches technologically, politically, or economically acceptable limit

FIGURE 1.2 Phases in the implementation of a waste reduction program.

emphasis depending on the current stage of industry's waste reduction program at the national scale.

The committee believes that distinguishing the phases of implementation of a waste reduction program provides a helpful guide for discussing the relative importance of the nontechnical considerations at different times and for different firms or industries. It provides a planning framework within which to discuss possible institutional and public policy approaches to achieve the desired reduction in generation of hazardous waste.

In the initial phase, external influences such as increasing costs of disposal, liability considerations, improved knowledge of health and environmental effects, increasing public concern, and increasingly stringent regulatory requirements for land disposal cause industrial management to become aware of the problem and begin to develop waste reduction strategies. The first steps in implementing a waste reduction program--the simpler, quicker, often least costly waste minimization approaches such as good housekeeping practices and separation of waste streams--are implemented in this phase. These approaches could substantially reduce the amount of waste that is generated.

In the development phase of a waste reduction program, the quantity or degree of hazard of waste generated is reduced as more sophisticated waste reduction methods are applied. During this phase, there is a sharper evaluation of options, greater attention to production process modifications that reduce the generation of hazardous waste, and increased development of improved or new control technologies. Implementation of newer and/or improved technologies and process modifications for waste abatement and reuse and recycling substantially decreases the amounts generated during this phase. The techno-

logical approaches generally result in greater capital expenditures than in the early phase.

In the mature phase, firms would design and build new plants with improved waste management practices and improved technologies as integral parts of the process. Eventually, the technologically, politically, or economically acceptable lower limit of hazardous waste generation would be approached. The acceptable limit would vary as improved technologies for waste reduction are developed and as political and economic conditions change. To achieve the most waste reduction that is technologically practical, it is likely that more capital would have to be expended and increasingly sophisticated waste reduction technologies implemented. As firms would have to undertake large capital expenditures in this phase, the need for a clear understanding of the relative risks associated with the remaining waste and for sound risk management increases. Risk management, though a relatively young concept whose techniques need to be developed, can be an effective tool for understanding the trade-offs between protection of public health and the environment through reducing generation of hazardous waste and costs of developing and implementing technologies to achieve this reduction.

The concept of phases in the implementation of a waste reduction strategy is not intended to define precisely the nature of a firm's waste reduction pattern. Rather, the concept is meant to convey the idea that as firms develop and implement waste reduction strategies, different factors become important. Public policy, to be effective in promoting waste reduction activities, must be responsive to these different considerations.

2

Factors Affecting Industrial Decisions About Hazardous Waste Generation

INTRODUCTION

Prior to the recent national focus on hazardous waste, industry had few incentives to reduce the generation of hazardous waste. As a result of legislative and regulatory changes implemented under the Resource Conservation and Recovery Act of 1976 (RCRA) and increased public awareness and concern, there now are important reasons for waste generators to consider using methods to reduce generation of hazardous waste. These reasons include the following:

- Substantially higher costs for disposal of hazardous waste
- Prospects of substantial liability for the costs of remedial (cleanup) actions
- Risks of third-party liability, even where a generator may not be directly responsible for improper disposal of hazardous waste
- Potential for adverse public relations
- Public opposition to local siting of hazardous waste management facilities

As discussed in the preceding chapter, the amount of hazardous waste reduction that has occurred in response to these incentives is difficult to document. Although waste reduction efforts have increased to some extent, the successes have not been uniform across different industries and within an industry. The committee believes that significant opportunities remain to reduce further the generation of hazardous waste. Government will need to make additional efforts to encourage firms to undertake this reduction.

The committee believes that public policies that directly control industrial processes through regulations would be extremely complex from an administrative and practical point of view. The sheer number of and variations in industrial processes throughout the country make effective administration of a program that specifies required changes in industrial processes very difficult. Moreover, waste reduction involves changes in manufacturing processes, which have generally been outside the traditional purview of environmental regulations. Therefore, public policy approaches other than direct regulation of manufacturing processes, such as incentives that reinforce industrial decisions to change production processes, are preferable. A close examination of the factors that affect industrial decisions about waste generation may reveal opportunities for public policy to encourage industries to undertake waste reduction efforts.

Industrial decisions about the generation of hazardous waste are the result of many choices made by manufacturers in the course of doing business and the incentives provided by society to favor some of these choices over others. Some of the choices that can be made by an individual manufacturer are illustrated schematically in Figure 2.1.

The manufacturer's choice of the final product (Step E) prescribes the choice of raw materials and processing procedures or process chemistry (Steps A and B). At this step, waste reduction through minimization and abatement could be considered (Step C). The choices, in turn, determine the quantity and kinds of residuals (Steps D and F). For purposes of this discussion, the noneconomic residuals can be divided into two categories--hazardous waste (Step G) and other waste (Step H). Management of the other waste is outside the scope of this study.

There are three possible dispositions for the hazardous noneconomic by-products of production processes (Step G). First, they may be recycled, reused, or otherwise processed to yield economically useful products (Step I). Second, there may be opportunities, such as those listed in Appendix A, for conversion of hazardous by-products to make them less hazardous or nonhazardous (Step J). Third, the waste may be placed in the environment (Step K).

Although Figure 2.1 is a simplification of actual manufacturing processes, it indicates that the generation of hazardous waste is the result of numerous interdependent technological, production, and marketing considera-

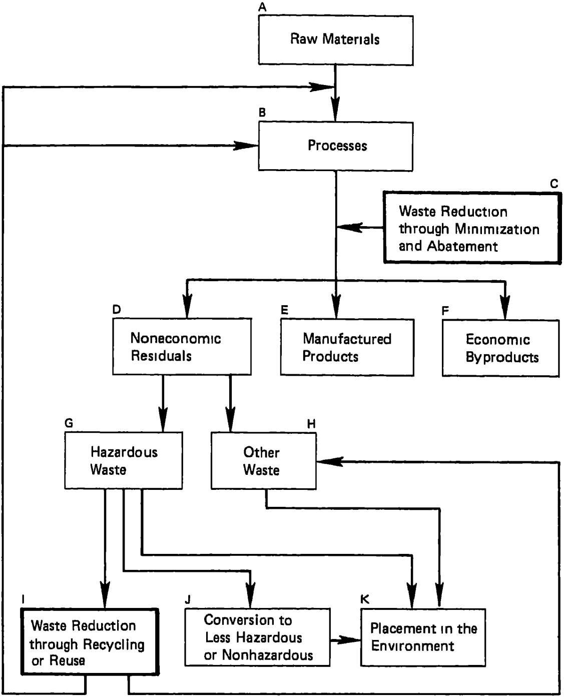

FIGURE 2.1 The waste production process. See text for an explanation of the steps.

tions. The schematic representation of Figure 2.1 would become more complex as additional interdependencies are identified, but in this theoretical framework the "solution" to the hazardous waste generation problem appears relatively simple; either increase the cost of hazardous waste disposal to the point where business

managers would choose not to generate the waste in the first place or make the cost of recycling or reuse so low (even negative) that industries would be moved to undertake recycling and reuse activities.

Economic forces, however, do not work as quickly or smoothly as theory might imply. Choices could be limited, for example, because information about existing technologies might not be available or attitudes within firms might impede change. Some considerations are not under the control of the corporate manager or production superintendent.

Table 2.1 presents the major factors affecting industrial decisions about the types and amounts of hazardous waste they generate. The previous chapter suggested that the role of each of the factors in industrial decisions depends on the phase of development of the particular firm's strategy for hazardous waste reduction.

The remaining sections of this chapter contain discussions of each factor and suggestions of opportunities for public policy to take the factor into account. The dynamic nature of the considerations should be kept in mind as each factor is examined in detail.

TABLE 2.1 Factors Affecting Industrial Decisions About the Generation of Hazardous Waste

- Availability of land disposal
- Attitudes toward change
- Availability of information about waste reduction methodologies
- Regulatory issues in reducing generation of hazardous waste
- Needs for research and development
- Capital costs
- Issues in assembling, processing, and sale of recycled materials
- Product quality standards

COST OF LAND DISPOSAL

Hazardous waste management in the past has been skewed in favor of land disposal, largely because costs were low and risks to human health and the environment attendant to land disposal were not appreciated. Land disposal historically has been the least expensive alternative. The low cost to waste generators of land disposal, however, has not adequately reflected the long-term costs to society of cleanup, possible health effects, irreversible environmental degradation, and various other consequences. The committee believes that the discrepancy between the "true" cost and the current cost of waste management options, in this case land disposal, is a crucial factor that must be addressed in order to promote actions to reduce the generation of hazardous waste. If the costs could be assessed adequately, economics would favor waste reduction or treatment over land disposal in many instances. However, an economic evaluation of this long-term true cost is probably not possible for the following reasons:

- The long-term transport and fate of land-disposed hazardous waste cannot now be reliably estimated, so that there are significant uncertainties in estimates of exposure.
- The long-term health effects of exposure to hazardous waste are largely unknown.
- There are continuing uncertainties as to how health and environmental effects should be translated into monetary values, even if these effects could be determined accurately.
- There are uncertainties concerning the appropriate discount rate for such an evaluation, i.e., what the appropriate discount rate would be to weigh society's responsibilities to future generations against its responsibilities to current generations.

The current cost of land disposal may not accurately represent the generators' total long-term costs either. For example, while it is generally accepted that the immediate out-of-pocket cost for landfilling renders it a relatively inexpensive option, some generators use landfills more sparingly than short-term economic considerations would indicate. This practice occurs for a variety of reasons, such as to avoid potential long-term liability in the event that waste leaks from

the disposal sites. Recent judicial and administrative decisions concerning the liability of generators for disposal site cleanup under the Comprehensive Emergency Response Compensation and Liability Act of 1980 (CERCLA; PL 96-510) have highlighted the fact that generators may be held liable for very large cleanup costs. Consequently, many generators are becoming aware of the potential longer-term costs associated with land disposal and are altering their dependence upon this waste management option accordingly. It is not clear whether additional liability requirements would heighten this effect, as statutory expansion of cleanup liability and judicial expansion of potential civil liability to injured third parties are already having a high impact on how companies do business (Hall 1983). In addition, in some instances certain wastes are restricted from land disposal on a categorical or volumetric basis.

The rising costs of land disposal already are becoming, and are likely to continue to be, an extremely significant factor motivating industry to consider changing their current waste management practices. For example, quoted prices from nine commercial waste management firms increased from $120-168 per wet metric tonne in 1980 to $168-240 per wet metric tonne in 1981 for landfilling of drummed hazardous waste, and increased from $44-55 per wet metric tonne in 1980 to $55-83 per wet metric tonne in 1981 for landfilling of bulk hazardous waste (Booz-Allen and Hamilton, Inc. 1982).

Public policy approaches, such as taxes and restrictions on land disposal, that maintain the current trend of increasing costs to generators for land disposal are likely to continue to promote interest in waste reduction activities. Fees and taxes on the landfilling of waste and waste-end taxes on the generation of waste, for example, are direct mechanisms for making other waste management options more competitive with use of landfills for some waste.

ATTITUDES TOWARD CHANGE

Attitudes toward changes in industrial processes or practices vary widely from firm to firm and affect the implementation of strategies to reduce waste generation. Waste generators may be reluctant to take risks with unproven technologies or to compromise other goals, may be ignorant (or mistrustful) of alternatives, or may

simply be uninterested in changing habits. These influences could delay or prevent consideration of waste reduction methodologies in the early phase of implementing a waste reduction strategy.

A large component of corporate resistance to the use of waste reduction methods comes from the managerial level. For example, where on-site processing of waste streams has been proposed to enhance opportunities for recycling or reuse, managers may be reluctant to accept the risks associated with reliability of the technology. This conservatism results from the business manager's important role of controlling current costs and allocating resources where the needs and expected economic returns are greatest.

During the design and development of new production processes, there may be a tendency to select proven technologies rather than to innovate with methods that may generate less waste. End-of-pipe treatment generally has been preferred over waste reduction processes because the former approaches often do not require changes in the production processes. Once a manufacturing process is implemented, there may be even greater reluctance to make major modifications in the operation. The risks of installing waste reduction methods include the following:

- Uncertain investment returns
- Production downtime
- Operational difficulties or product quality problems
- Potential loss of proprietary information to a waste reduction consultant

A "crisis orientation" among management can also inhibit the implementation of waste reduction programs. As discussed in Appendix B, an organized and comprehensive waste reduction program is centered on an exhaustive and systematic analysis of the reduction potential for each waste stream a firm produces. In contrast, a firm may apply one isolated reduction measure at a time in response to new issues or regulatory measures. In some cases, this piecemeal approach to waste reduction may lead firms to deemphasize waste reduction as soon as they have made one incremental adjustment and to reassign the engineers responsible for the innovation to other, more traditional tasks.

The responsibility for increased attention to waste reduction does and should extend throughout a corporation

or a manufacturing facility to the production line, where reduction ultimately must occur. Labor may resist technological or procedural changes either because of a reluctance to change habitual practices or because jobs are perceived to be at risk. But successful waste reduction depends on the day-to-day cooperation of production employees, who often are in the best position to identify some kinds of waste reduction opportunities. They also are the ones who must implement new techniques or practices. Often one of the most effective first steps in a waste reduction strategy is to foster good housekeeping practices in the shop, a step only production employees can implement.

Ideally, firms may want to ensure that a corporate-level commitment to waste reduction is understood and accepted at all levels. In practice, this goal often is elusive, partly because the individuals responsible for waste management at larger companies usually are not those responsible for overseeing research, engineering, or production processes. Those involved in product development or process design may not recognize problems with waste disposal or the benefits of waste reduction. Waste management officers in manufacturing may see their role as securing the lowest-cost means for legal waste disposal, often overlooking other possible objectives of more comprehensive management strategies such as recycling, reuse, or process changes.

The committee believes that in the early stages of waste reduction efforts, good housekeeping and other opportunities for waste minimization can be effectively exploited. These opportunities tend to cost little. Educational programs and information dissemination provide the most promising public policy directions for lowering attitudinal resistance and increasing the drive to seek out and implement these types of activities.

Education of the design and development engineer on the desirability of waste reduction can be valuable, either as part of the engineer's formal education or as part of on-the-job training. Public institutions and professional societies could work with engineering schools to ensure that study of the impacts of concentration, source separation, and internal recycling on waste generation becomes part of the standard curriculum for process engineers. Dissemination of information about opportunities for waste reduction can be enhanced through trade shows, printed material, conferences, and perhaps via government-funded demonstration projects. It

could be that those responsible for plant operation simply are not fully aware of the actual costs in lost yield, waste-handling costs, disposal costs, and environmental liability associated with the waste stream. If the actual costs and opportunities are clarified, reasons for applying new waste reduction technology may become more clear.

Application of waste-specific accounting methods could be beneficial in overcoming initial resistance to change. With proper accounting, information could become available on actual waste production, characteristics, variability, and disposal costs.

AVAILABILITY OF INFORMATION ABOUT WASTE REDUCTION METHODOLOGIES

Some analysts argue that there has been little exchange of information about the waste reduction techniques already in use by some companies (Hirschhorn 1983, Sarokin 1983). Reducing the generation of hazardous waste provides a company with a temporary competitive advantage in a business where waste management costs are a significant fraction of gross production or transaction costs. Thus many firms seem reluctant to release information about their waste reduction practices because doing so might provide competitors with information on confidential processes or the technology being used. This lack of communication may delay or prevent firms from considering changes in their waste management practices and implementing simple, low-cost measures to reduce waste generation. Lack of information may particularly inhibit the adoption of waste reduction strategies by small businesses, which often do not have the resources to explore opportunities for waste reduction on their own. It is interesting to note that the United States has very few citations in the Economic Commission for Europe's Compendium on Low-and Non-waste Technologies (Economic Commission for Europe 1981).

Part of the reluctance of industry to disclose information may be attributed to the fact that the regulatory system is information-driven. Once the success of one company in waste reduction becomes widely known, the regulator often wants other firms to follow its example. The originating firm often receives little economic return for the innovation, and its competitors benefit from the ability to use processes in whose development they did not participate.

Opinions differ on the degree of importance of the confidentiality problem. In industries in which processes are fairly uniform throughout the industry, such as the electroplating and petroleum industries, confidentiality may be a lesser consideration. The competitive advantage between firms is gained by more competitive products, decreased total costs, or increased levels of service. In industries where the competitive advantage results from differences in processes, such as the chemical and pharmaceutical industries, confidentiality considerations may be more important.

The confidential nature of waste reduction methods may be particularly significant for limiting the availability of information about techniques for waste abatement and minimization involving process modifications. The availability of information about recycling and reuse of hazardous waste may also be limited, not only because of the potential economic advantage gained by successfully recycling and reusing waste, but also because of the possibility that competitors will acquire knowledge of production processes through examination of the waste stream.

Most waste exchanges (see section below on issues in assembling, processing, and sale of recycled materials for a description of waste exchange) and commercial recyclers offer very stringent confidentiality assurances to the generators who use their services. These agreements often incorporate elaborate nondisclosure procedures. Many vendors offering recycling equipment have proprietary processes so that potential users cannot develop the method themselves. Attention to confidentiality among vendors of recycling equipment may be greater than it is among the generators themselves. However, no clear consensus has developed concerning the degree to which confidentiality considerations actually inhibit the effectiveness of waste exchanges (Herndon 1983).

Patents do not generally provide a means for protecting the confidentiality of waste reduction methods used by a firm. Many waste reduction methods are not patentable because the methods involve changes in operating practices that are well known. For example, separation of waste streams to permit recovery or improvements in housekeeping practices may reduce the generation of hazardous waste; these practices are not generally patentable though they may need to be adapted to specific circumstances.

The committee is not optimistic about the possibilities for overcoming the problems posed by confidentiality of

information through stricter agreements or other arrangements. Firms will always be reluctant to disclose information about their processes that provide them with a competitive advantage. However, governments, trade associations, universities, and other institutions can provide mechanisms for dissemination of generic information about waste reduction techniques. Some of these opportunities include the following:

- Educational programs for generators, engineers, and plant operators
- State-established authorities, university-based groups, trade associations, and other appropriate groups to disseminate information
- Competition for novel means to reduce generation

Workshops, conferences, technology transfer sessions, and other educational programs can provide generic information on how waste can be reduced in certain industrial categories. States or trade organizations may wish to fund studies of these generic possibilities and to provide estimates of return-on-investment and other economic and technical incentives to encourage the industries to implement the procedures. These types of efforts would be most successful in industries where processes are not highly confidential. In addition, in the education of process engineers an increased emphasis on residuals could focus on the impacts of concentration, source separation, and internal recycling on the generation of waste.

Publicly funded authorities or university-based groups could explore opportunities for waste reduction in specific industries. The information obtained would be made freely available.

State-sponsored competitions for industries to develop novel means for reducing generation of waste could be a mechanism to encourage industries to disclose methodologies for waste reduction. Besides a cash prize and some very favorable publicity, the company may have to disclose the methodology used so that other firms can benefit from their work.

REGULATORY ISSUES IN REDUCING THE GENERATION OF HAZARDOUS WASTE

With the enactment of the Resource Conservation and Recovery Act in 1976 (RCRA; PL 94-580), hazardous waste was defined and given special attention by the federal government. Previously, limited attention to hazardous waste had been given in the Clean Air Act (PL 91-604), Clean Water Act (PL 92-500), and other federal legislation. The regulatory program, together with progeny at the state level, is assumed to have been a major impetus for the changing patterns in the generation of hazardous waste. However, this assertion is difficult to demonstrate statistically because the formal definition of hazardous waste has changed from time to time and the techniques for estimating volumes generated are imperfect.

The increased costs of treatment and disposal imposed by a regulatory program are assumed to lead to a reduction in hazardous waste generation. There are, however, a number of features associated with the design of a regulatory program that will maximize this result. Not surprisingly, a poorly designed regulatory program may even provide disincentives to the reduction of hazardous waste. In this section, several features of the regulatory program are described that are critical if the program is to encourage, rather than impede, reductions in waste generation.

Virtually all regulatory programs for environmental protection have five elements in common:

- Definitions of the regulated activities
- Procedures for setting standards
- Procedures for issuing permits to engage in the regulated activities
- Procedures for monitoring and inspection
- Procedures for enforcement

The functional definition of hazardous waste contained in RCRA is very broad (42 USC 6903). A vast array of chemical wastes are considered hazardous. Included, for example, is waste from particular manufacturing processes or waste having certain characteristics (such as ignitability). In addition, activities associated with these materials at any point after generation are also subject to regulation according to the "cradle to grave" concept.

In light of the generally broad sweep of the statute, it is not surprising that the standards-setting process also is rather extensive. The statute and the regulatory program provide not only for a wide range of standards associated with the design and performance of a permitted facility, but also for the responsibility for these materials. Thus there is a manifest system designed to track all hazardous waste transported off the site of generation (40 CFR 263.20 through 263.22), as well as provisions establishing long-term (30 years) responsibility to monitor and maintain disposal sites (40 CFR 264.110 et seq.).

The permitting, inspection, and enforcement provisions, with a few exceptions, are not notably different in construct from other environmental protection programs. The manifest system can be viewed as a unique aspect of the inspection program, virtually mandating continuous accountability for hazardous waste transported off-site regardless of the government's ability to carry out inspections.

Four attributes of the regulatory program appear to be critically important for industrial decisions about hazardous waste generation. They are as follows:

1. Definition of hazardous waste--Would changes in the operative definition result in greater reductions?
2. Predictability of the program--Is the future of the hazardous waste regulatory program sufficiently predictable to cause a reduction in waste generated?
3. Stringency of standards--Are the standards appropriate incentives for reducing waste generation?
4. Degree of success in implementation--Has the implementation of the program encouraged waste reduction activities?

Definition of Hazardous Waste

By statute, hazardous waste is a subset of solid waste. Solid waste is defined in RCRA (42 USC 6903) as "any garbage, refuse, sludge . . . and other discarded material, including solid, liquid, semisolid, or contained gaseous material. . . ." EPA interprets solid waste as a material that (40 CFR 261.2):

is discarded or is being accumulated, stored or physically, chemically, or biologically treated prior to being discarded; has served its original intended use and sometimes is discarded; or is a manufacturing or mining by-product and sometimes is discarded.

Although EPA further defines "discarded" as "abandoned (and not used, reused, reclaimed, or recycled) or disposed of," to some extent it asserts jurisdiction over materials that are recycled, reused, or recovered except if these processes are universal practices in the industry.

The definition of hazardous waste as it now stands may inhibit national progress in waste reduction in two distinct ways. First, it excludes certain categories or sources of waste from the regulation, which removes external pressures on those generators to control their waste generation. Second, those wastes that are included within the definition are treated in a uniform regulatory manner regardless of whether the waste is recycled, reused, treated, or disposed; therefore there is little impetus to develop more desirable management techniques for these materials.

With regard to the first point, RCRA and the regulations developed to implement it contain a series of blanket exemptions. Certain hazardous wastes have been excluded from regulation for a variety of reasons including technological feasibility, economic impact, or administrative complexity. Most notable are the exclusion of generators of volumes smaller than 1000 kg per month (40 CFR 261.5) and exclusions for certain industries such as the mining and smelting industries (40 CFR 261.4).

The committee suggests that existing legal exemptions be evaluated and a specific program for their removal be developed where appropriate. This examination should determine the reason for the exemption, determine the extent of the problem that could be addressed by removing the exemption, and develop a specific plan for addressing the factors causing the exemption. For example, if technology is not available, then either a decision should be reached on a program to develop the technology, or an evaluation should be made as to whether the hazard justifies other government-mandated changes in the production process.

With regard to the second point mentioned above, the regulatory system does not readily allow for flexibility in the management of a material once it has been defined

as hazardous. The standards and procedures are, in theory, equally rigorous whether a material is to be permanently stored, reused, or treated so as to be less hazardous or nonhazardous. In addition, the same regulatory scheme applies regardless of the degree of hazard associated with the particular waste. For example, a flammable waste perhaps would be appropriately subject to rigorous regulation if stored permanently, but might be treated with greater flexibility if burned as a fuel. The net effect of treating all options for handling a particular waste with rigorous uniformity is that the generators are not likely to prefer any particular alternative to disposal unless there are economic benefits associated with it.

To encourage waste reduction practices, the committee recommends modifications to the regulatory definitions to include the degree of hazard. This concept is discussed in further detail in Office of Technology Assessment (1983). In addition, the procedural requirements of the statute--i.e., the administrative structure of the regulatory program in contrast to the substantive standards or requirements--could be modified as discussed above in order to encourage recycling and reuse. For example, permitting and manifesting requirements for recycled and reused waste could be made more modest. The changes in procedural requirements would not require amendments to the current statutory definitions.

A currently available source of flexibility is EPA's existing authority to "delist" certain hazardous materials (40 CFR 260.22). EPA lists broad generic categories of waste or specific process streams as hazardous because they contain certain "hazardous constituents" and are therefore "toxic." Once a material is listed, it and any waste materials derived from it remain by definition hazardous (40 CFR 261.3). An operator who recycles hazardous waste by removing hazardous constituents (e.g., solvents such as toluene and metals such as chromium, lead, and zinc) from the waste stream must still dispose of the remaining material as hazardous, regardless of the efficiency of the recovery process. The derivative waste can only be declared nonhazardous through a case-by-case review by EPA. It is difficult for a generator to have such materials "delisted" because EPA has been reluctant to specify hazard thresholds, particularly for organic hazardous constituents. Thus an operator recycling a portion of a waste has no assurance that the processing

will result in a material not classified as hazardous. Consequently, there is little regulatory inducement to recycle a waste. The committee recommends that EPA give consideration to using the delisting process to encourage the use of processes that reduce the amount or hazard of hazardous materials that must be disposed in the environment.

Notwithstanding the foregoing discussion, there is some concern that EPA has been too liberal in allowing reuse and recycling techniques deemed to be common to an industry to escape the reach of RCRA completely. The committee could not develop data to address this issue, but emphasizes that changes in procedural requirements to allow greater flexibility for the use of recycling and reuse methods should be carefully designed and administered to avoid risks to public health and the environment.

Predictability of the Program

There has been a high degree of variability in the regulation of hazardous waste over the past fifteen years. Although explicit regulation came about only with the passage of RCRA in 1976, many of the actual businesses and processes involved in hazardous waste management developed in response to earlier legislation, particularly the Clean Water Act and the Clean Air Act. Regulatory practices involving volatile organic chemicals and pretreatment requirements under the Clean Air and Clean Water Acts, respectively, are areas where these statutes specifically address hazardous materials.

The degree to which the entire system of regulations is implemented in a predictable and consistent fashion has a major effect on the net generation of hazardous waste. Failure to maintain a consistent and predictable program is likely to affect the generation of these wastes adversely, because firms are less likely to adopt definitive plans for waste reduction in the face of uncertainty. The predictability of a program's implementation is affected both by the care with which it is implemented and by the degree to which loopholes in it affect its viability. Failure in either case reinforces avoidance of expenditures and the adoption of a "wait and see" attitude. Therefore unpredictability not only delays commitments to undertake waste reduction practices, but also is likely to hinder implementation of reduction programs already begun.

Given the history of the implementation of RCRA, the committee concludes that the regulatory program can only be characterized as unpredictable. Eight years after the passage of RCRA, its regulatory provisions are not in full effect anywhere in the country. Beyond that, it is unclear as to whether the final program, when implemented, will be managed by the federal or state governments. Whatever the reasons for this delay--bureaucratic inertia, program complexity, political considerations, inadequate technical information--the effect has been to defer the use of many of the techniques necessary for reducing generation of hazardous waste.

The committee is not optimistic about the possibilities for improving the predictability of the regulatory program in the near future. In a fundamental sense, predictability depends upon a political consensus among government, industry, and the general public. The vigorous public debate about RCRA, its implementation, and the proposed amendments suggests that it will be some time before this consensus will be established. There are several reasons for this:

- The purposes for regulating hazardous waste are not well defined or uniformly shared. The overall goal of protecting health and the environment generally is widely accepted. However, a lack of means to accomplish the goal and uncertainties concerning both risk and effectiveness of controls for a vast array of materials stand in the way of achieving the goal.
- The significant public concern over wastes that are carcinogenic, mutagenic, or teratogenic and whether _any_ level of exposure is safe calls into question any decisions taken in the regulatory program.
- Implementation of RCRA depends to a high degree on deployment of new technology and the concomitant expenditure of large capital costs. A natural result is that industry will resist if benefits are not clear.

Specific steps could be initiated, however, to begin to address this issue. A system of waste classification based on hazard would clarify which materials will be given greatest attention in the regulatory program. An improved system of public awareness, education, and involvement could be initiated to begin to develop the consensus among the public, industry, and government necessary for achieving a predictable program.

In the near term, a series of steps can be initiated that will move toward greater program predictability. For example, government should clearly show its regulatory intent for these materials by developing a priority plan for implementation of RCRA. A comprehensive review could be undertaken to locate and eliminate inconsistencies, such as the relationship between RCRA and the pretreatment program under the Clean Water Act, and loopholes, such as the waste-oil program, in the regulations. A program plan could be developed by EPA detailing the manner in which RCRA will be implemented in those states not qualifying for delegation.

Stringency of Standards

Standards that are too strict, too weak, or highly variable can thwart progress in reducing hazardous waste generation. In this discussion, "standards" refers to both design and performance standards, as well as to procedural standards such as the manifest system mandated by RCRA. The term does not refer solely to some specific numerical requirement. In the preceding section, it was suggested that overly rigorous standards affecting techniques of reuse and recycling may discourage the use of these techniques. Elsewhere in this report it has been suggested that insufficiently strict standards for landfilling also may impede the reduction in generation of waste.

It is theoretically clear that more stringent standards will impose additional costs and therefore reduce the generation of waste. The committee concludes that regulations should be written to achieve health or environmental goals and should be made as stringent as necessary to achieve these goals. Nonetheless, excessive restraints, unwarranted in light of perceived threats to public health or environmental quality, should be avoided.

There are certain areas where changes in the standards would bring about a reduction in waste generated, and where such changes are appropriate to protect public health and the environment. For example, the following actions may be appropriate to protect public health and, at the same time, encourage reduction in generation of waste: (1) restricting materials allowed to be landfilled, (2) rapid phasing out of old, inadequate fills, and (3) strengthening requirements for long-term care. Such changes would raise landfilling costs and bring

about a reduction in generation, depending on relative costs of other treatment and disposal options.

Degree of Success in Implementation of the Program

Implementation involves the setting of standards, issuing of permits, and inspection and enforcement. The slow pace with which RCRA initially was implemented likely did not encourage industry to pursue waste reduction as vigorously as might have been expected during the 1970s. Recently, the situation appears to be improving. This year, for example, EPA has established a priority procedure that will require new permits for landfills and incinerators under the full provisions of RCRA.

The committee does, however, wish to emphasize that the current trend toward stronger program implementation must be continued if reduction efforts are to be maximized. As EPA or states undertake implementation of the full regulatory program of RCRA, adequate resources must be allocated to ensure that implementation is successful.

There is some reason to believe that this needed vigorous allocation of resources will not take place unless a substantial new commitment is made at both the state and the federal level. It appears that perhaps fewer than half the states will qualify for full delegation of RCRA. The committee is aware of no specific budgetary plans within EPA that would enable it to acquire the new resources to implement a complete regulatory program in all the unqualified states. Such a requirement would pose a substantial challenge to EPA. Available resources at the state level may also not be adequate. After two years of interim authority at the state level, the noncompliance rate for phase I of the RCRA program is over 60 percent in the priority areas of groundwater monitoring, financial, and closure requirements (W. Ruckelshaus, U.S. Environmental Protection Agency, letter to officials in state environmental agencies, April 4, 1984). Resources and strong program direction will be necessary to improve this situation.

NEEDS FOR RESEARCH AND DEVELOPMENT

Residual materials are associated with almost all manufacturing processes. If the ultimate societal goal is to reduce waste generation to the lowest feasible level, then the need for research and development, taken to mean the aggregate activities needed to devise and demonstrate technologies leading to as-yet-unproven means for reducing the volumes of hazardous waste generated, is an important one.

Methodologies exist to reduce hazardous waste generation, but they are not universally used. Often there are obstacles to implementation. For example, in processes employing liquid-liquid extraction to reclaim potentially hazardous solvents, the efficiency of mass transfer depends on fluid velocities. In specific applications, the waste stream temperature, flow rates, pipe sizes, and other factors affecting fluid velocities must be evaluated; in some cases in-place testing of mass transfer is needed. These efforts are for adapting a developed technique to a particular situation. In the case of liquid-liquid extraction, one would conclude that a technique was available and that research was not needed to develop a new technology. However, unless scientific and engineering staff were aware of this solvent recovery procedure and were available to conduct tests on design and to implement this solvent recovery process, the unavailability of methodologies would be <u>perceived</u> as a major constraint to reducing generation.

A number of individual facilities, corporations, or industrial subcategories may have already implemented available techniques and may have reached their practical limits of waste reduction given currently available technology. For this group, new technologies will be necessary for further improvement. There are relatively few such instances, however. On a national scale, research and development of advanced reduction technologies is not crucially needed until the existing opportunities are implemented and their impact known. There are a multitude of opportunities for adapting simple, low-cost practices already available, for example, spray rather than tank rinsing in electroplating or similar processes to reduce the amount of contaminated solution requiring disposal; separation of cooling water to avoid mixing with contaminated materials and to allow reuse of the water; substitution of water-based adhesives

for solvent-based ones; and caustic and acid reclamation and reuse.

In the national perspective, as more reduction in waste generation occurs, new techniques to accomplish even greater waste reduction will need to be developed. The importance of research and development thus will increase with time as the majority of industries implement currently available techniques and see the need to undertake further reduction. Facilitating research and development in certain industries, those for which new technologies would make a significant difference, eventually will become an important consideration in public policy.

The current need among a substantial majority of industrial generators is to encourage their adoption of existing methods. This implementation requires substantial resources for technical assistance, particularly for small firms, and will lead to a steady increase in the need to develop more complex methods for reducing the generation of hazardous waste. Thus the need for research and development will generally become important in the future when existing techniques have been fully utilized on a national scale.

The perception that waste reduction methods are not available currently has a much broader effect than does the actual lack of available techniques; both the perception and the true needs can be addressed through public policy. For example, means to address the needs might include the following:

- Devoting resources to demonstration of existing methods in a wide variety of actual situations
- Implementing educational programs for generators, engineers, and plant operators
- Funding a limited number of groups for research and development

Instead of devoting the majority of the resources to research, typically at universities and research organizations, appropriate groups could be supported to promote actual implementation. Such groups might be organized at the technical level to provide guidance for the plant engineering needed to tailor available techniques to specific industrial facilities lacking in-house personnel.

Educational programs also could provide access to information about available waste reduction practices or

to those familiar with such methods. Trade associations could be helpful in keeping the industries informed about available techniques. Local universities and colleges, trade associations, and other appropriate groups could organize workshops and conferences for industry groups.

In the select cases for which existing methods have been exhausted, research and development is needed to achieve further reductions in the generation of hazardous waste. Funding of groups to perform research on waste reduction methodologies would be a valuable investment. Because research and development has a long lead time, a well-developed, ongoing research effort on waste reduction methods will allow an orderly transition to future national waste reduction efforts as more industries utilize available methodologies and need to develop new approaches.

CAPITAL COSTS

In many cases, the lower operating and disposal costs achievable with more efficient processes may enable waste reduction initiatives to pay for themselves and eventually to improve the profitability of a process. There are many examples cited in the trade and popular press as well as the technical literature (Campbell and Glenn 1982, Huisingh and Bailey 1982, Ministere de l'Environment 1981, Royston 1979). However, many companies, especially firms whose plants are antiquated, may not be able to justify the fixed capital investment some technologies require. Competition, domestic and international, often makes companies reluctant to invest in waste reduction equipment or process changes when economic advantages are not clear.

Capital costs of equipment may become significant after industries have exploited the low-cost opportunities for reducing generation that generally represent the first steps in waste reduction. Capital costs could be a significant constraint as more capital-intensive approaches are needed to achieve further reductions.

Public policy approaches that lower the actual capital costs of waste reduction to industry may be important in the future as the nation progresses in its waste reduction effort and incentives are needed for implementing sophisticated, high-cost technologies. These approaches could include the following:

- Low- or no-interest loans, with liberal repayment plans, for reduction expenditures. The loans could be offered by government to cover the cost of an environmental audit to determine the optimal ways to reduce waste generation as well as the capital costs of the change itself.
- Guaranteed loans extended to firms by private investors, to make financing of waste reduction measures easier to obtain.
- Tax deductions, tax credits for waste reduction initiatives, or exemptions from the sales tax or import duties for recovery or reduction equipment.
- Direct government subsidies to firms developing reduction methodologies, in order to reduce the start-up price of these investments.
- Government actions to allow and encourage smaller firms to pool their resources to implement a joint reduction strategy or construct and operate joint resource recovery facilities.

A problem with any type of government subsidy for waste reduction is in implementing the program and establishing whether the firm in fact qualifies for the subsidy. The approaches discussed above need to be analyzed in detail to determine their merit in various situations.

ISSUES IN ASSEMBLING, PROCESSING, AND SALE OF RECYCLED MATERIALS

Recycling is an important option for reducing the generation of hazardous industrial waste. Both on-site and off-site recycling can be significant on a national scale. In this section, the focus is on impediments to off-site recycling and how these can be overcome. On-site recycling generally involves the same factors as waste abatement and minimization, as discussed elsewhere in this chapter.

According to EPA estimates (Westat 1984), of the 264 million metric tonnes of hazardous waste generated in 1981, only a small portion was recycled. Nevertheless, recycling appears to be an increasingly attractive option to generators; the number of generators recycling waste increased from 5700 prior to 1981, to 6100 during 1981, and to 7800 after 1981.

Waste exchanges are one mechanism for promoting recycling of hazardous materials. They provide a mechanism for a user of materials to identify a waste generator producing a reprocessed or reused material that can be used. Typically, listings of wastes wanted and wastes available are provided to the exchange, which publishes the lists periodically. Inquiries about listed materials are forwarded by the exchange to the generators. This arrangement allows firms to advertise their feed-stocks or waste without disclosing proprietary information that might compromise their competitive advantage (Dorn and McAdams 1982).

Passive exchanges or clearinghouses broker only information on materials wanted and wastes available. They are usually small, nonprofit groups, subsidized or wholly funded in some instances by state and regional governments. Because passive exchanges focus on materials of unknown or unrecognized value (i.e., materials generally regarded as waste), they do not compete with commercial or industrial brokers of by-products. Active exchanges or materials exchanges, on the other hand, actually accept or purchase wastes, reprocess them, and sell them at a profit. Therefore they usually handle waste with high market value (Dorn and McAdams 1982, Gaines 1982).

The first waste exchange in the United States began operating in St. Louis in 1975. As of 1982, 34 waste exchanges were active in the United States and 17 in foreign countries (Dorn and McAdams 1982). The effective-ness of waste exchanges and the problems associated with their use for hazardous waste are described by Gaines (1982).

Waste exchanges have met with varying degrees of success in this country (Herndon 1983). The obstacles to successful operation of waste exchanges are largely the same as those that impede the development of other off-site commercial recycling facilities, as discussed below.

Several successful recycling programs currently are making effective and economic use of hazardous waste. The best example is solvent recycling both on and off the site of commercial facilities. The technology for solvent recovery (distillation) is well established (U.S. EPA 1981). Solvents contaminated with a wide variety of impurities can be successfully processed. The resulting products readily meet exacting specifications and are sold into the market below the price of virgin solvents.

Other waste streams may be less successfully recycled, because of one or more technological, economic, practical, or other factors. There are several technical obstacles to the recycling of hazardous waste. Nominally identical waste streams may differ between plants and between batches from the same plant; this variability in raw material can make processing difficult. Recyclers in general have difficulty, and hence tend to avoid, separating and purifying complex mixtures of waste. In some areas, technology is not available, and in other areas, technology has been developed but is not economical.

There also are economic constraints to establishing recycling facilities. Transportation costs, for example, can be a major determinant of the economics of recycling high-volume, low- concentration waste. The uncertainty of quality and quantity of waste can lead generators to lack confidence in their supply of recycled materials; this can inhibit the development of markets for recycling facilities.

Certain other practical considerations also make recycling less attractive. Industry often is faced with liabilities connected with waste transfer, such as under the "joint and several" liability provisions of CERCLA. In general, liability issues have yet to be clearly resolved under either state or federal regulations (see Hall 1983). In response to this concern, many generators prefer on-site to off-site recycling. However, industry often may perceive on-site recycling as an undesirable venture into another business.

Concerns about confidentiality and trade secrets often hinder waste exchanges, as discussed under the section, "Availability of Information About Waste Reduction Methodologies." In addition, continuous revisions in regulations and uncertainties about future regulations on recycling make entrepreneurs reluctant to develop recycling facilities. Another factor that may limit the availability of recycling facilities is public resistance to the siting of such facilities.

These issues are related to many of the other factors described in this chapter. The development of markets for recycled materials is in part related to the predictability of the regulatory system because a market will develop in response to a regulatory system only if the latter is predictable. In addition, product quality standards are involved in situations where more lenient product specifications would enable generators to use recycled materials in their production processes.

Approaches that could encourage the development of recycling facilities include the following:

- Increasing procurement of recycled materials or materials containing some recycled component. The Resource Conservation and Recovery Act (42 USC 6002) requires EPA to encourage the use of recycled material in government projects, "given reasonable levels of price and performance." In addition, increasing procurement by industry would encourage recycling, although industry would tend to procure recycled materials only if it was economic. Study is necessary to delineate materials that are good candidates for procurement programs, including, for example, paints, thinners, and ferric chloride wastes.
- Streamlining federal and state regulations so that they treat recycling plants more like ordinary chemical processing plants. With tighter enforcement and financial assurance requirements, recyclers could be regulated with more flexibility without unreasonable risk to health and environmental quality.
- Increasing public education to demonstrate that properly managed recycling can mean less danger from waste, not more. This may ease the difficulties in siting recycling facilities.
- Increasing financial assistance to waste exchanges so that they can play a more active role in arranging for recycling and reuse of materials.

PRODUCT QUALITY STANDARDS

A product quality standard is a description of a commercial product. The standard may have been developed by the supplier of the product, by the purchaser (particularly military and civilian government procurement), or by a standards-setting organization. Regardless of its origin, the purpose of the standard is to describe the characteristics of a product in a manner that can be relied upon by both buyer and seller. The specifications that make up a product standard may relate to any characteristic of the product, including the aesthetics of the product, its ability to function in its intended application, health and environmental risks, and acceptable levels of impurities.

Product quality standards can be a factor in industrial decisions about waste generation. A nonfunctional standard specifying the aesthetic characteristics of a

product could, for example, limit the opportunities for implementing waste reduction technologies. Modifying product quality standards could increase the opportunities for process change or redesign of products leading to waste reduction and thereby lower the technological, economic, or politically acceptable limit for waste generation. For example, in the electroplating industry bright cadmium plating is important for the aesthetics of the product but is not necessary for protection of the finish. If existing specifications for certain cadmium-plating applications were relaxed, cadmium and cyanide concentrations in the waste could possibly be substantially reduced.

Relaxing product quality standards would enable some industries to reduce their generation of hazardous waste through process changes and raw material substitution important for waste abatement and minimization. In some instances, recycled materials could be substituted for virgin raw materials as feedstock in the production process. These opportunities undoubtedly vary between types of industries and even between processes within an industry. The opportunities must be studied on a case-by-case basis.

Relaxation of standards also could expand opportunities to prevent some off-grade products from being discarded as hazardous waste. This would be possible where out-of-specification products are hazardous and are discarded as waste instead of recycled, mixed with other batches of products to produce a blend that is within specifications, or sold for uses that can tolerate out-of-specification products. Whether such opportunities are substantial can vary enormously depending on current commercial practices.

In general, the initiative to alter a product standard rests in the hands of the organization that established the standard. For example, a standard established by a manufacturer of a product can be changed by the manufacturer, though the manufacturer may be influenced to initiate such changes by pressures from customers, government, other standards-setting organizations, or the public. Unfortunately, the organization setting the standard often does not recognize or is not aware of the hazardous waste that may be generated because of that standard. This gap is a severe constraint.

Changes in a standard established by a commercial organization may be difficult to make because of competitive pressures. Nonetheless, there may be some instances in which either a purchaser or a seller has

established specifications that no longer have significant commercial importance but that do affect the amount of hazardous waste that is generated.

The consumers of products play a significant role in taking initiatives to change product quality standards. Consumers include the government, both civilian and military, and industries as well as the public at large. Though they generally would not be aware of the relationship between particular specifications and the generation of hazardous waste, consumers nonetheless can identify those specifications that are essential from the point of view of the utility of the products they purchase. For example, industrial or government consumers could invite suppliers to bid against pared-down specifications. They might also talk with suppliers to bring the relationship between specifications and waste generation into better focus. These actions could be particularly important for government in its role as a consumer of products.

Individual corporations can examine their product specifications to identify instances in which obsolete or nonfunctional specifications stand in the way of reduction of waste generation. Trade associations and standards-setting organizations can consider whether modification of specific, nonfunctional specifications could lead to a reduction in the generation of hazardous waste. Also, federal, state, and local government agencies can initiate dialogue with suppliers to identify specific opportunities for standard rewriting that would start to focus on waste reduction. As noted earlier, however, the connection between a product standard and the generation of hazardous waste is poorly understood by the standards-setting organization and the public. This constraint can be overcome by (1) clearly identifying the linkage in a reasonably quantitative way and (2) implementing an educational program to disseminate this information.

Conceivably, explicit attention to this subject by a specially constituted group organized under the auspices of an appropriate private organization or public institution could identify--industry by industry--the specific opportunities that merit attention. Finally, the relationship between specifications and waste reduction may be an appropriate subject for attention at academic institutions, particularly by means of industry-sponsored research grants.

3
Approaches for Encouraging Hazardous Waste Reduction

INTRODUCTION

The preceding chapter described the factors that affect industrial decisions about hazardous waste generation and the influence of public policy on the factors. The relative importance of the factors in the decision-making process of corporate waste management undoubtedly varies according to the type and size of the industry. As was pointed out earlier, small businesses are faced with a different set of problems than are large ones. Often the former may lack information about existing waste reduction practices, may lack technical personnel to investigate waste reduction, may be very resistant to change, and may be particularly sensitive to the capital costs of waste reduction. The importance of each of the factors will also change with time as firms and industries undertake and implement waste reduction activities. The phases in a general waste reduction program are described in Chapter 1 (see Figure 1.2).

On the basis of the discussion in Chapter 2, the committee concludes that in the initial phase of implementation of waste reduction strategies--when industries or individual plants consider changing their waste management practices and implement simple, available, low-cost waste reduction methodologies--the availability of relatively low-cost land disposal options, attitudes toward change, regulatory issues, and availability of information about existing waste reduction methodologies are the factors that most greatly affect industrial decisions about waste generation.

In the development phase, other factors become important as industries require higher capital expenditures and research and development efforts to achieve

additional waste reductions. In addition, after the simpler, low-cost steps have been taken, firms may investigate potentials for recycling or product changes.

Eventually, if trends to reduce generation are encouraged to continue, a technological, political, and economic limit for waste reduction will be reached. In this mature phase, the challenge to society is to define the acceptable limit of waste reduction in light of changing political, economic, and technological conditions.

Some firms and individual plants have achieved considerable success in waste reduction and are well along in implementing their respective reduction programs. The committee is convinced, however, that currently the nation as a whole is in the early stages in the development and implementation of hazardous waste reduction programs. Thus the major need for public policy now is to inform and encourage generators to make the goal of waste reduction an integral part of their day-to-day decisions.

Because the importance of the factors discussed in Chapter 2 changes over time and varies from industry to industry and firm to firm, no single policy can hope to encourage industries to reduce their generation of hazardous waste. A complement of policies combining educational programs, economic incentives and disincentives, and regulatory approaches is needed. Because changes in industrial processes necessary for waste reduction are difficult to control through regulatory action, nonregulatory approaches for public policy require particular emphasis. All of these policies should be flexible in order to address the changing needs of firms. Table 3.1 summarizes opportunities suggested throughout the report for public policies to encourage waste reduction.

APPROACHES FOR ENCOURAGING FIRMS TO REDUCE HAZARDOUS WASTE GENERATION IN THE INITIAL PHASE

Public policy approaches that would be most effective in the initial phase would emphasize the following:

- Maintaining the current trend toward changing land disposal practices
- Adjusting the regulatory system to encourage, not impede, waste reduction efforts

- Providing for nonregulatory actions such as dissemination of information about successful, economic waste reduction methodologies.

Cost of Land Disposal

The current cost of land disposal options is perhaps the most significant factor affecting industrial decisions about waste generation. Society has recognized that land disposal options such as landfills and surface impoundments are not always a secure method for managing hazardous waste. Continued reliance on such options may impose significant risks to human health and the environment. Although the "true" long-term costs to society of such options cannot be accurately determined, it seems likely that current costs to the generator do not reflect the net costs to society.

The committee believes that public policy should attempt to increase the costs to generators for the use of land disposal options that pose risks to public health or the environment. If the costs of land disposal adequately reflect the long-term costs to society, waste reduction would be more economically attractive to industry than it is now.

Recent trends show an increase in cost to generators for land disposal. For example, costs of landfill management have increased, due to requirements for liners, specialized covers, leachate collection and treatment, and groundwater monitoring systems; these costs are passed on to the generators disposing of their waste in landfills. Potential costs of liability for remedial action and costs of liability insurance also add to the costs of land disposal, as do costs of treatment prior to disposal. In addition, assessment of fees and taxes have increased costs to generators. Some states, for example California and New York, have imposed landfill restrictions on certain materials, and other states are considering such regulatory action. All of these factors have decreased the attractiveness of landfills and surface impoundments as waste management options.

The committee believes that the trend of increasing costs of land disposal will continue. The committee supports such increases, as long as they reflect the costs of protecting the public health and the environment, as a positive step in encouraging a national effort to reduce generation of hazardous waste.

TABLE 3.1 Public Policy Approaches to Reduce Generation of Hazardous Wastes

	Phase I Initial phase. Firms consider changing waste management practices and implement low-cost waste reduction opportunities	Phase II Development phase. Firms develop and implement comprehensive strategies for waste reduction, often involving more capital-intensive technologies	Phase III Mature phase. Reduction in generation approaches technologically, politically, or economically acceptable limit
Nonregulatory approaches	• Educational programs for generators and engineers • Dissemination of information through state-established authorities, university-based groups, trade associations, or other groups • Competition for novel means to reduce generation • Allocation of resources to demonstration of existing methods in a wide variety of actual situations • Greater assistance to waste exchanges so they can play a more active role in arranging for recycling and reuse of materials	• Increased public education to ease siting difficulties for recycling facilities • Public support for R & D needed to adapt existing waste reduction technologies to individual circumstances • Increased procurement of recycled goods • Low- or no-interest loans, guaranteed loans, or direct subsidies for waste reduction • Tax deductions or credits for waste reduction expenditures • Support for joint reduction strategies and facilities for small generators • Study of opportunities for modifying product quality standards on case-by-case basis and modification of standards where appropriate	• Definition of acceptable limits for waste reduction through a program of risk management • Support for basic research on new waste reduction technologies

Command-and-control regulations	• Evaluation of existing legal exemptions to determine whether such exemptions inadvertently reduce incentives for waste reduction • Changes in procedural requirements to allow greater flexibility for recycling and reuse • Strengthening some standards to encourage waste reduction practices: (1) restrictions on materials allowed in landfills (2) rapid phase-out of old, inadequate fills (3) strengthened long-term care requirements • Effective program implementation to assure that the incentives for waste reduction reflected in regulatory standards are also reflected in actual practice	• Greater use of EPA authority to "list and delist" materials to encourage recycling and reuse • Incorporation of degree-of-hazard concept in the regulatory framework
Cost of land disposal	• Increasing the cost to generators for land disposal to a level consistent with the total social cost of land disposal options	

Regulatory Approaches

The regulatory system is an important factor shaping industrial decisions about waste generation (see Chapter 2 on regulatory issues). The committee concludes that regulations should be made as stringent as necessary to achieve public health and environmental goals. Nonetheless, excessive restraints, unwarranted in light of perceived threats to public health or environmental quality, should be avoided.

The regulatory system should encourage firms to undertake waste reduction activities where consistent with environmental and health goals. One of the regulatory actions that could be considered in this regard is to evaluate existing exemptions and modify where appropriate. Exemptions from RCRA, such as the small generator and mining exemptions, may inhibit progress in waste reduction even though they may exist for valid extraregulatory considerations. The exclusion removes external pressures on those generating the hazardous waste to undertake reduction programs.

Certain changes in hazardous waste regulations would be appropriate to protect public health and the environment and at the same time would encourage reduction in waste generation. Consideration should be given to (1) restricting materials allowed to be landfilled; (2) rapid phasing out of old, inadequate fills; and (3) strengthening requirements for long-term care.

Effective implementation of the regulatory program is also important to encourage waste reduction. As indicated in Chapter 2, the current trend in program implementation is favorable. Improvement must continue, however, because illegal behavior can seriously impede the adoption of reduction efforts.

The regulatory system could encourage movement toward waste reduction by changing procedural requirements of statutes to allow greater flexibility for recycling and reuse. Once a waste is defined as hazardous, it is generally treated in the same regulatory fashion regardless of its ultimate fate. Thus, as the system stands now, generators have no incentive to prefer waste reduction to disposal unless there are economic benefits associated with the former.

Many of the regulatory considerations concern procedures that have been established at the federal level. Therefore the regulatory approaches to encourage waste reduction may require implementation at the federal, rather than the state or local, level.

Nonregulatory Approaches

Waste reduction activities involve changes in industrial processes that are generally difficult to control through command-and-control regulations. The full range of public policies therefore must emphasize nonregulatory approaches.

Although generators must develop their own techniques for reducing waste, there are common elements that may be incorporated in all programs. Information is gathered on each waste stream, plans are developed for reducing the high-priority waste in each identified waste stream, and the economic and technical feasibility of the alternative plans is assessed (see Appendix B).

The greatest current national need is for firms to take advantage of the many opportunities for waste reduction using simple, low-cost methodologies proven in successful current programs. In general, there are few, if any, financial impediments to this approach. The committee concludes therefore that while financial incentives such as funding for high-risk ventures and tax credits for waste reduction equipment may be useful to some industries or firms that need to undertake waste reduction activities that entail high costs, public policies to promote education and information dissemination are likely to be more effective in the near term. Although the committee cannot predict how much waste will be avoided through effective programs of information exchange, such programs are likely to have an important effect, particularly on the smaller firms for which the lack of understanding of the possibilities and economics of waste reduction represents a very critical barrier to implementation of known techniques. The opportunities for public policy to address these concerns include the following:

- Educational programs for generators, engineers, and plant operators
- Dissemination of information through conferences, workshops, technical literature, and so on
- State-established authorities, university-based groups, chambers of commerce, and other appropriate groups to work with firms to implement waste reduction practices
- Innovative approaches, such as competitions for novel means to reduce the generation of waste or annual awards for achievement, which encourage industries to share information about waste reduction successes.

Local and state governments, trade groups, universities, and other organizations familiar with the local industries and waste management problems are better able to carry out the information dissemination activities than is the federal government. For example, workshops can be organized by local groups to disseminate information and provide opportunities for generators to trade information on possibilities for waste reduction (see, for example, Partington et al. 1983). Programs in some states, such as North Carolina (Governor's Waste Management Board 1983), New York (New York State Environmental Facilities Corp. 1983), and Georgia (John C. Nemeth, Georgia Institute of Technology, presentation to EPA Small Business Ombudsman and Office of Compliance, Planning and Policy, May 1984), disseminate information on waste reduction and provide technical assistance to waste generators. These opportunities should be reviewed by other states embarking on such programs.

APPROACHES FOR ENCOURAGING FIRMS TO CONTINUE WASTE REDUCTION PROGRAMS IN THE DEVELOPMENT PHASE

As firms or plants move from the initial phase, they may have to use more sophisticated and expensive methods to achieve further reductions. Some firms may already be facing this challenge. As the waste reduction effort on a national scale achieves this level of sophistication, public policies will need to shift emphases to take into account the factors that come into play.

Regulatory Approaches

In the development phase, the techniques for waste 'uction are increasingly sophisticated. The regulatory jram needs to be equally sophisticated and flexible. h regulatory approaches could include the following:

Greater use of EPA authority to "list and delist" erials to encourage recycling and reuse

- Incorporation of the degree-of-hazard concept in e regulatory framework.

Nonregulatory Approaches

When waste reduction requires significant investment of capital, policies incorporating financial incentives and support for research and development to adapt sophisticated waste reduction techniques to particular circumstances may be important. Typical approaches for public policy of this type could include the following:

- Increased procurement by government and other organizations of recycled materials
- Low- or no-interest loans, guaranteed loans, or direct subsidies for reduction expenditures
- Tax deductions or credits for waste reduction expenditure;
- Support for joint reduction strategies and facilities for small generators
- Support for groups conducting research and development in waste reduction methodologies

For small generators with limited availability of capital for waste reduction, financial incentives may be particularly important.

Other types of considerations may also be addressed in the development phase of waste reduction programs. Examples include opportunities for altering product quality standards and facilitating the siting of recycling facilities.

CONSIDERATIONS IN THE MATURE PHASE

In the mature phase, the technologically, politically, or economically acceptable lower limit of hazardous waste generation would be approached. The challenge to society will be to define this acceptable limit through a risk management program. The relationship between waste reduction and reduction in risk to public health and the environment will need to be clarified to define the acceptable limit. Society will need to weigh the costs of further waste reduction against benefits achieved.

To achieve waste reduction in this phase, it is likely that increasingly sophisticated waste reduction technologies that require significant capital expenditures will be needed. Basic research on new methods for waste reduction may be an area of importance for public policy. As the issues that will be important in this phase cannot

be foreseen completely, the committee suggests that public policy be implemented incrementally and be flexible to adapt to circumstances as they arise.

Development of a risk management program and basic research in new methods for waste reduction are both activities that may require long lead times. The committee suggests that these activities be initiated and supported now to allow the nation to progress efficiently to the mature phase of waste reduction.

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Appendixes

Appendix **A**

Hazardous Waste Management Methodologies

In Chapter 1 of this report, Figure 1.1 shows the relationships between the options a waste generator would consider in managing hazardous waste. This simplified hierarchy has three tiers: waste reduction; conversion of hazardous waste to less hazardous waste; and placement of residuals in the environment. The focus of this study is on the upper tier, which is divided into four categories: abatement, minimization, reuse, and recycling. These reduction categories are discussed in Chapter 1. Waste reduction methodologies are presented on an industry-by-industry basis in Campbell and Glenn (1982), Economic Commission for Europe (1981), and Ministere de l'Environment (1981). Although the report emphasizes the nontechnical aspects of waste reduction, this appendix is included to discuss techniques for the other two tiers and to provide a perspective on the role of waste reduction in the waste management hierarchy.

The second tier (conversion) includes all forms of waste treatment. The Resource Conservation and Recovery Act describes treatment as (42 USC 6903):

> Any method, technique, or process including neutralization, designed to change the physical, chemical, or biological character or composition of any hazardous waste so as to neutralize such waste or so as to render such waste nonhazardous, safer for transport, amendable for recovery, amenable for storage, or reduced in volume.

Some kinds of treatment can have an effect similar to that of waste reduction in reducing the environmental burden of hazardous waste. Often the generator will evaluate a combination of reduction and treatment options

in choosing a waste management scheme. A wide variety of generic technologies are included in each of the treatment categories (see Table A.1). Several reviews of these general processes are available (Governor's Office of Appropriate Technology 1981, Office of Technology Assessment 1983, National Research Council 1983).

The third tier in the simplified waste management hierarchy includes options for placement of residuals in the environment. Table A.2 lists some generic classifications for these options. It is important to note that complete elimination of placement in the environment as an option for hazardous waste management

TABLE A.1 Generic Treatment Technologies

Physical/chemical	
Neutralization	Electrophoresis
Hydrolysis	Freeze drying
Reduction	Freeze crystallization
Precipitation	Chlorinalysis
Evaporation	Catalysis
Dechlorination	Photolysis
Oxidation	Electrolysis
Stripping	Dewatering
Ion exchange	Membrane technology
Liquid ion exchange	Thickening
High-energy electron beam	Emulsion breaking
High-gradient magnetic separation	Adsorption techniques
	Land treatment
	Solvent extraction
Biological	
Activated sludge	Waste stabilization ponds
Aerated lagoons	Mutant bacteria
Anaerobic digestion	Deep shaft aeration
Composting	Fluidized bed bioreactor
Enzyme treatment	Powder-activated carbon
Trickling filter	Land treatment
Rotating biological disc	Municipal sewage treatment plants
Thermal	
Rotary kiln	Liquid injection
Fluidized bed	Vertical tube reactor
Molten salt	Infrared furnace
Plasma arc	Co-incineration (industrial boilers)
Cement kiln	Ocean incineration
Microwave plasma discharge	Evaporation
Multiple hearth	Calcination
Pyrolysis	Wet air oxidation

TABLE A.2 Options for Placement of Residuals in the Environment

Secure landfill	Seabed implacement
Engineered landfill	Above-ground storage
Structural landfill	Co-disposal
Deep well injection	Land treatment
Ocean disposal	
Geologic isolation	

is probably impractical. There will always be irreducible residuals created by many of the options in the first two tiers; therefore it is not feasible to prohibit all landfilling or use of other placement techniques. The committee has avoided the use of the term "ultimate disposal" for this category because some of the options actually are storage rather than disposal options. "Disposal" also suggests that monitoring and continued responsibility for the material is not necessary and that it will cause no further concerns. Neither of these suggestions is true in all cases.

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Appendix B
A Typical Waste Reduction Program

A typical strategy for conducting a waste reduction program in an industrial facility is described in Figure B.1. The strategy, based on the experience of committee members, outlines the generic, logical steps a firm could undertake in implementing a waste reduction program. A waste reduction program following this general strategy would have the following elements. First, information is gathered on each waste stream, including source of generation, physical/chemical characteristics, quantities, variations in rate of production, regulatory designation of hazardousness, means by which it is handled within the plant, and costs of managing the

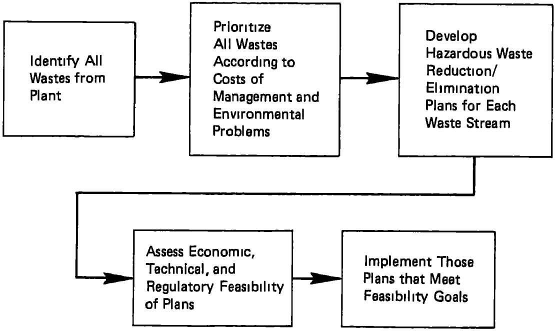

FIGURE B.1 Model waste reduction strategy.

TABLE B.1 Considerations in Assessing the Feasibility of Alternative Waste Reduction Plans

- Alternative Process Description--an overview of the technology (methodology) including theory and application
- Technology Flow Diagram
- Material Inputs--description of the influent material streams identified by physical/chemical properties
- Effluents and Residuals--description of the products and waste streams including residuals-handling requirements
- Implementation, Reliability--description of technical feasibility including proven nature of technology
- Process Application--description of current waste management applications of new process as well as future potential
- Economic Considerations--an overview of general capital and operating/maintenance costs, where available
- Energy Requirements--description of power demands and energy intensity of application
- Resource Recovery Potentials--an overview of materials' recovery potential
- Risk Factors--an overview of potential environmental and health threats posed by the product and process residuals
- Institutional Considerations--description of regulatory and possible permitting considerations

waste. Next, priorities are established for all the wastes according to the environmental problems they pose, regulatory considerations, and their contribution to the annual waste management cost at the facility. Consideration is also given to how changes in production processes, such as the phasing out of a particular product, may alter the total waste stream.

A plan is then developed for the reduction of each identified waste stream. The plan focuses on the physical or chemical properties of the waste that are of concern and need not focus on the total volume or weight of the stream. This focus is important because it aims at the items that create the primary environmental or health impacts and also facilitates the selection of waste reduction methodologies. Options should be examined in

each of the four categories (abatement, minimization, reuse, and recycling).

Upon completion of this stage of the management strategy for the higher priority wastes, a process to assess the economic and technical feasibility of the options can begin. Table B.1 outlines some of the considerations that may be encountered in this process. By using a unified approach in this step, comparative economic data can be derived to document the success of the program. To date, this information has not widely been collected in industry, even though it has been obtained in other areas such as wastewater and energy conservation programs. A company should continually reevaluate its options over time to adapt its waste prevention programs to changing economic, technological, or regulatory conditions.

Appendix C
Additional Documents Reviewed by the Committee

The following list contains articles and documents that, in addition to those cited in the report, were reviewed by committee members during the course of the study.

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Appendix D
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Appendix E
Biographical Sketches of Committee Members

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ANTHONY O. FACCIOLO, JR. (deceased) was the owner of a small business, Alexandria Metal Finishers, Inc., in Alexandria, Virginia. He was active in the American Electroplaters' Society, where his responsibilities on the Board of Directors included research and development in hazardous waste management. His training was in law; he had received an L.L.B. and J.D. from Georgetown University in 1964.

SAMUEL GUSMAN is a private consultant in Taos, New Mexico. He was formerly a senior associate with the Conservation Foundation, where his work included research, analysis, and facilitation of policy dialogues on environmental issues related to chemicals. Previously, he was on the staff of a chemical company, Rohm and Haas, and director of research and president of a subsidiary pharmaceutical company. Gusman served as the chairman of the Office of Technology Assessment Advisory Panel on Technologies and Management Strategies for Hazardous Waste Control. He received a Ph.D. in physical chemistry from Brown University in 1950 and an M.S. in 1947 and a B.S. in 1946 in chemical engineering from the Massachusetts Institute of Technology.

ROBERT A. LEONE is a Lecturer in Public Policy at the John F. Kennedy School of Government at Harvard University. Previously, he was associate professor at the Harvard Business School. His research interests include government regulation and operating policies of private firms. Leone received a Ph.D. in 1971 and an M.A. in 1968 from Yale University in economics and a B.A. from Harvard University in 1967.

MICHAEL R. OVERCASH is professor of chemical engineering and professor of biological and agricultural engineering at North Carolina State University. His research is on technologies for hazardous waste management; the terrestrial (soil and groundwater) impacts of chemicals; and on the structure and economics of waste reduction across all industrial categories. Overcash has conducted many in-plant investigations for specific industrial facilities, and recently completed a major pollution prevention study for the U.S. Air Force. He currently has a research grant from the State of North Carolina to implement waste reduction technologies. Overcash received a Ph.D. in chemical engineering from the University of Minnesota in 1972, an M.S. from the University of New South Wales in 1967, and a B.S. from North Carolina State University in 1966.

PHILIP A. PALMER is a senior consultant on solid waste management with E.I. du Pont de Nemours and Co. in Wilmington, Delaware. He has worked with du Pont in many capacities since 1964, including assignments in

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STEFFEN W. PLEHN is vice-president of Fred C. Hart Associates, Inc., in Washington, D.C. He works in the areas of policy, technical, economic, and environmental issues in solid and hazardous waste. Previously, Plehn was the deputy assistant administrator for solid waste at EPA and was responsible for the agency's implementation of the Resource Conservation and Recovery Act. He received an M.P.A. from Harvard University in 1961.

ROBERT B. POJASEK is manager of the Hazardous Materials Group at Chas. T. Main, Inc., in Boston, Massachusetts. He works in the area of managing the use of industrial chemicals. He has consulted with government and industry in hazardous waste management and has conducted studies on the opportunities for waste reduction. Pojasek is active in similar efforts in the American Chemical Society, World Health Organization, and U.S. Air Force. He received a Ph.D. in chemistry from the University of Massachusetts in 1973 and an A.B. in chemistry from Rutgers University in 1970.

MICHAEL E. STREM is the president of a small chemical company, Strem Chemical, Inc., in Newburyport, Massachusetts. He serves as chairman of the Division of Small Chemical Businesses of the American Chemical Society. He is a former president of the Newburyport, Massachusetts, Chamber of Commerce and a former chairman of the Peabody, Massachusetts, Environmental Control Commission. Strem received a Ph.D. in 1964 and an M.S. in 1961 from the University of Pittsburgh in chemistry and an A.B. in 1958 from Brown University.

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